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NO ACOUSTIC BENEFIT TO SUBTERRANEAN CALLING IN THE CICADA *OKANAGANA PALLIDULA* DAVIS (HOMOPTERA: TIBICINIDAE)

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Most male cicadas produce a loud calling song to attract their mates. Sound pulses are produced when specialized muscles buckle the rib-strengthened chitinous membranes, the timbals, located on the dorsolateral surface of the first abdominal segment. Sound pulses are then modified by several body components (Pringle 1954, Bennet-Clark and Young 1992) before being radiated through the tympana (Young 1990).

Male cicadas generally use an accessible perch from which they advertise their presence to conspecific females. We came across an exception to this behavior south of Lone Pine, Inyo County, CA, on 15 July 1994. We encountered the cicada species *Okanagana pallidula* Davis singing in a scrub habitat. As we began collecting, we noticed that one individual continued to sing as we approached and was very difficult to locate on the plant. By circling the plant we found that the sound was actually coming from the ground near the base of the plant and not from on the plant itself. After clearing some grass we could see a hole about 1 cm in diameter from which the sound emanated. Within the hole we could see the head of a cicada that was calling from this subterranean site.

We measured intensity levels from males calling from burrows and from plants to determine if there is an acoustic benefit for the cicadas calling in burrows. Peak sound pressure levels (SPL) were recorded with a Brüel & Kjaer 2235 SPL meter, a Type 4155 1/2″ prepolarized condenser microphone, and a UA 0237 wind screen. The system had been calibrated with a Brüel & Kjaer 4230 portable sound pressure calibrator. The SPL meter was used in the linear frequency mode. The peak setting has a time constant of less than 100 ms and was used to ensure that rapid sound transients were measured. Measurements were made perpendicular to the long body axis with the apparatus oriented medially along the dorsal surface of a singing cicada at the thorax-abdomen junction or directly above the hole in which a cicada was singing. This procedure minimized any inconsistencies between readings due to possible asymmetries in the sound field produced by cicadas (Aidley 1969, MacNally and Young 1981). Each intensity measurement was made at a distance of 50 cm. The distance was kept constant by placing a 1/4″ (6.5 mm) dowel, attached to the SPL meter, near a calling cicada. If the cicada was disturbed by placement of the SPL meter, the reading was made only after the normal calling pattern had been reestablished. All intensity measurements are relative to 1×10^{-16} W/cm^2.

Power output was determined using the following equation:

$$Q = 4\pi r^2(I)$$

where Q = sound power (W), r = distance from source in cm (= 50 cm), and I = intensity reading for the individual (dB). Since intensity is measured on a logarithmic scale, all intensity measurements (dB readings) were converted to pressure levels (W/cm^2) prior to calculating the statistics. Mean power output was then used to calculate mean sound intensity at 50 cm for each species.

Intensity measurements are summarized in Table 1. SPL values recorded for cicadas calling from within a burrow are lower than values recorded when the animals were calling from a plant; however, the values are not significantly different (t = 1.49, d.f. = 3, P = .1159). A greater number of trials may provide

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TABLE 1. Intensity of *Okanagana pallidula* calling songs. Song power was calculated from individual measurements. Mean power was used to determine the mean sound pressure level for each perch. Measurements are relative to 1×10^{-16} W/cm^2.

Location of calling perch	Sound power (mW)	Mean intensity (dB)	Range (dB)
Exposed calls	1.106 ± .6823 (n = 3)	85.46	83.4–87.8
Subterranean calls	0.340 ± .1190 (n = 2)	80.34	79.1–81.3

the statistical significance. We were unable to find a large number of individuals singing from burrows. Similarly, the vast majority of specimens calling from plants did not permit our approach to a distance necessary to collect a greater number of intensity measurements.

Subterranean calling has been described for the cicadas *O. pallidula* (Davis 1917, 1930, 1944, Beamer and Beamer 1930) and *O. vanduzeei* (Distant) (Beamer and Beamer 1930). Crickets have also been shown to call from burrows (Bennet-Clark 1970, 1987, Ulagaraj 1976, Forrest 1983, Kavanaugh 1987, Walker and Figg 1990); however, burrows fashioned by crickets increase the intensity level of their song (Bennet-Clark 1987). Subterranean calling in *O. pallidula* appears to decrease song intensity rather than increase sound transmission.

Subterranean calling may function as a predator avoidance behavior in *O. pallidula*. The difficulty we had in extracting a cicada from its burrow supports this assumption for vertebrate parasitoids. Burrows appear to be connected to nymphal development chambers, which can reach a depth of 2 ft (61 cm; Beamer and Beamer 1930). They represent a relatively safe location from which to call and may provide protection from acoustically orienting parasitoids. Many predators have been shown experimentally to orient to the calls of cicadas (Soper et al. 1976) and other acoustic insects (Walker 1964, Cade, 1975, Mangold 1978, Bell 1979, Buchler and Childs 1981, Sakaluk and Belwood 1984, Fowler and Kochalka 1985, Tuttle et al. 1985, Belwood and Morris 1987). The protective value provided against dipteran or other parasitoids to cicadas calling from burrows remains to be determined.

The majority of the population appears not to call from a burrow as indicated by the proportion of individuals we found calling from plants versus those calling from burrows. Perhaps the benefits of a protected calling site limit the chances of a male to attract a female successfully. The males may eventually abandon their burrows to increase the chances of interacting with females. It would be interesting to investigate the ontogeny of subterranean calling in cicadas.

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